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BIOGENESIS

AS EXHIBITED IN

DECOMPOSITION, PUTREFACTION, OR DECAY,

By ROBERT BELL, M.D.,

F.F.P.S.G., &c.

Read before the Philosophical Society of Glasgow.

GLASGOW:

JOHN PRYDE, SAUCHIEHALL STREET.

1872.

PHOTO-MICROGRAPHS BY DR. BELL.

Plate 1.

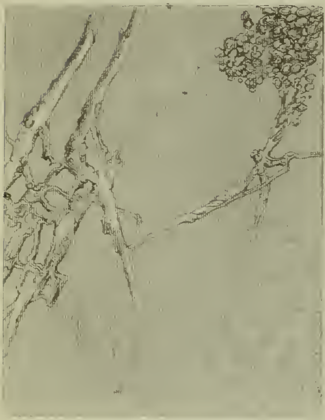
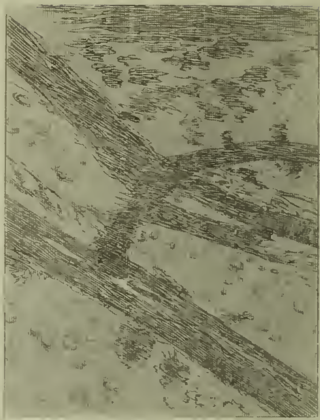


Plate 2.



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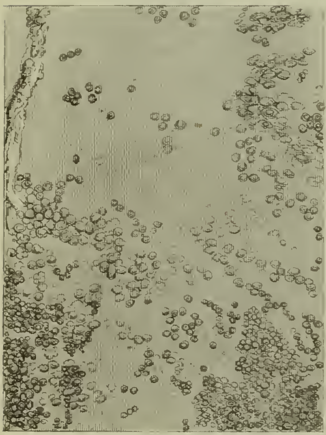

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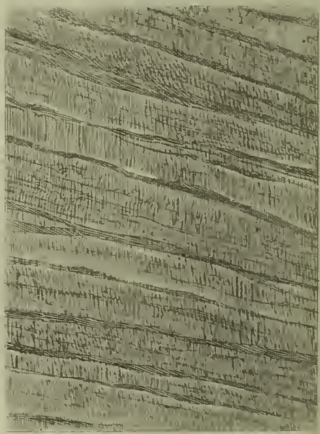

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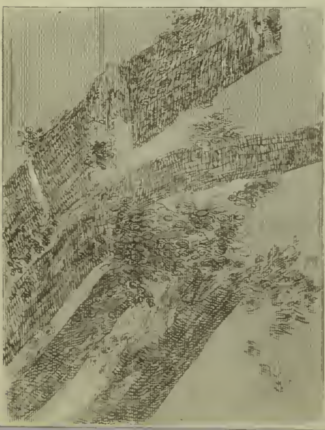
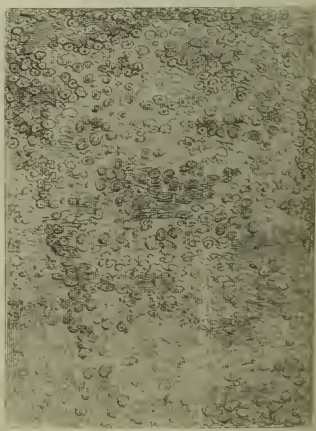


Plate 6.



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MR. PRESIDENT AND GENTLEMEN,

In coming before you on this occasion it is my intention to discuss some points bearing upon the Decomposition of animal and vegetable substances, and it will be my object to show what relationship the development of minute organisms has to this process of decay. The subject which I have chosen will not permit me to go beyond the *development* of microscopic life. I will not attempt to dip into the mysteries which envelop its origin. It will not be my aim to de-

monstrate what life is as an essence, yet I believe that the life, as an entity, of an Amœba or a Bacterium* and that of the higher animals are essentially one, and therefore as difficult to produce in the one instance as in the other. I will not allow my imagination to range through ages when this world was *void*, yet *full* of latent energies were these only allowed to exercise their power upon bodies then quite foreign to the earth. Nor will I permit vague theory to tread, though ever so gently, upon these prevital epochs, to disturb that silence which is so characteristic of creation: no I will not imagine what took place when old Father Time was yet a boy. It will be far from me to presume to follow through boundless space the aimless flight of meteors created by the crash of worlds. I will not guess for how many generations they held on in their reckless wanderings till by chance they found a resting place upon our then barren earth, and as if by magic made it teem with life. Nor will it be my object to show how, by a peculiar power quite foreign to life as we find it, a parent may give origin to a being higher in the scale of life than itself, and thus lend myself to the theory of man's *ascent*, for we can hardly call it *descent*, from an inferior animal. I will *ape* no such knowledge. These theories have been discussed as we all know, and I doubt not but that every one of us have made up our minds whether they appear tenable or otherwise.

The germ theory of putrefaction is not an idea of to-day, many different opinions have been and are still held anent it. Some have supposed that decay is produced by the action of the atmosphere, that it is essentially a chemical process; others affirm that minute organisms or Bioplasm† are the *results* of decomposition, putrefaction, or decay, while others hold that the change is produced by these organisms, and that they instead of being brought into existence by decomposition are in reality the agents which accomplish the disintegration; in

* Forms of microscopic life.

† Bioplasm or living matter requiring the aid of the microscope to detect its presence.

other words the germs of these microsymes* which are swarming in our atmosphere, and cover all substances, when they find a suitable pabulum, external circumstances being compatible, immediately become developed into the minute cellular bodies which are so numerous in all putrefying substances, and reproduce themselves at an alarming rate of rapidity, in their growth applying the substance on which they dwell to their nourishment, and by a force possessed by them break up the tissues into their elementary states, applying to their own use that which is suitable to them for food. I might add that this power is possessed by all living bodies, no matter how low or how high their place in creation. Thus, we perceive that the atmosphere does indirectly cause decomposition, not, however, as we shall see by any intrinsic property which it possesses, but by being the medium of introducing the agents necessary to effect the change. It is owing to this power of resolving a compound body into its different constituents, that these organisms obtain nourishment, and at the same time set free gases, which are more or less offensive according as the tissues acted upon contain more or less nitrogenous matter; and by so doing make known to us the presence of decay, the proximity of which is so prejudicial to health. Thus, the very agents which to fulfil the designs of providence produce putrefaction, at the same time warn us of danger. I have said, the more highly nitrogenized the substances undergoing decay, the more fœtid is the smell arising from them; or it might be put thus, the higher in the scale of being the decomposing matter is, the more fœtid is the stench arising from its decomposition; thus vegetable matter, while decaying, emits a much fainter odour than animal tissues undergoing the same process. I am not certain, however, that the same kind of microsyme may be able to produce only one kind of gas, *e.g.*, we know that the Torulæ or Yeast fungus, when acting upon certain substances sets free Carbonic Acid, whilst other organisms,

* Microsymes expresses much the same idea as Bioplasm.

both confervoid and animalcular, are capable of setting free nitrogenous or ammonical gases; yet, it does not appear to me to be impossible that the Torulæ might in other circumstances be able to set free other than Carbonic Acid gas. It would appear that the different products are excreted from the organisms, and that they are not simply generated by some peculiar action upon the substance. My impression is that it must first pass into the organism as nourishment, and then become free by a process of osmosis.* This seems a plausible theory, but, as yet, it must remain among the long list of things not definitely settled; however, there does not appear to be the slightest doubt that the fœtid smells, the products of, and indicating decomposition, and by which we are warned of its presence, are brought about by the agency of these minute living particles. This, however, I will, later on, endeavour to prove by experiment. In the meantime, it is demonstratable that putrefaction is relative to the growth and multiplication of, is coincident with, and dependent upon the development of minute living particles. I would first direct your notice to the great utility of such tiny beings, and then turn your attention to the views of two or three observers on the subject of their origin. We cannot estimate too highly the very important place that these organisms hold in the economy of nature. Parenthetically, I would here like to draw your attention to a familiar example of the action of minute cells in producing decomposition of a particular kind. I refer to the legion of cells pervading the coats of the alimentary canal. Here we have an indisputable example of decomposition being brought about by the action of, what might be termed, microscopic life. In this particular instance we have a temperature maintained which is conducive to the change. These cells take up what is specially applicable to their several wants, and in the excreta, we have the refuse which they have rejected. It is by the decomposing effect

* Osmosis or the law of diffusion of gases.

of the cellular portion of the canal that we have produced on the one hand that which nourishes the body, and on the other that which constitutes the fæces.

But to return to the consideration of our subject, we may learn most important lessons of diligence and usefulness from these tiny beings. They demonstrate to us how the very meanest of God's creatures adds its mite towards sustaining and helping forward the great plan of this world's existence. Were it not for these living particles the elementary substances of which our grasses, grains, and fruits, and those of the bodies of animals are composed, must sooner or later become exhausted; but after vegetation and animals have served their day, and part with life, this innumerable army of workers set too, and liberate the different elementary atoms, so that they may again go through the same cycle of life, death and decay. This thought is worthy of full consideration, for if we can establish the usefulness, nay, the absolute necessity of these microscopic living beings, we go a long way towards establishing their mode of origin and development. One thing, then, we accept as fact, and that is, the process which we call putrefaction, decomposition or decay, and to which I would add disease, is always accompanied, if not produced, by the development of minute living bodies; *e. g.*, we have these brought into existence in the putrefaction of animal and vegetable substances, in the souring of milk and beer, in decaying cheese, in the formation of pus in ulcers, and wounds, and abscesses, in the death of animals from the fly fungus, or the Typhus or Cholera or Scarlatina germ. And here I would make a suggestion, which, after mature consideration, I thoroughly believe to be a fact—that we can *never* have decay in any of its different varieties without we first have the vitality of that acted upon less than that of the germ producing the change, or we would have decomposition setting in on living tissues, and disease asserting its sway on healthy bodies. Then, again, we must have external influences favourable to the growth and

life of these organisms, *e.g.*, we see how cold retards putrefaction, likewise an excess of heat, whilst a moderate degree of warmth is highly favourable to the process. Moisture is another essential to decomposition, *e.g.*, dry hay will keep any length of time, but allow it to become moist and how soon does it decay. Indeed anything with a dense and dry cuticle can be preserved simply because the germs producing the change are unable to penetrate the dense covering, or to act upon it in any way.

Then, with reference to disease which must also be included in this group as being a kind of decomposition, for is it not caused by a growth, and multiplication of bioplasm in the blood, which is quite foreign to it? Take, for example, poison entering by an external wound—the virus of a rattlesnake. It is ascertained that this is made up of minute cells sus pended in a fluid which in itself is held to be innocuous, and it is the rapid multiplication of these cells in the blood which produces such rapid decomposition of the tissues, and death of the victim. Take, again, the vaccine disease which we are all so familiar with, here we have scarcely a drop of vaccine lymph placed upon a raw surface, and with the result in a few days of having these multiplied to an enormous degree. But then it may be asked, how is it that a person may be exposed to, say the poison of Typhus fever, and yet he does not take the disease, whilst another who was similarly situated was infected? This question is not difficult to answer. In the one case we had a healthy constitution, with its vitality unimpaired, or at any rate in such a healthy condition as to enable it to withstand the onset of the disease producing germ, whilst in the other we had at the time, I will not say a weaker constitution, *cæteris paribus,* but a condition at the time of lowered vitality; in short, we had in the first a vital force stronger than that of the disease germ, and, therefore, able to cope with it, and in the second we had the reverse. But another problem naturally suggests itself,—how does it so often come to pass that the snake-bite acts as a poison, that the

vaccine disease is so uniformally produced? or to generalise the question,—how is it so constantly, nay, almost invariably the case that poisons entering by wounds produce their dire consequences, whilst those entering by the lungs may produce no effect whatever? This most important question is likewise of easy solution, for in all such cases we have the part where the poison enters weakened by some external agency, and thus prone to afford nourishment to the invading germs; these therefore multiply at the expense of the weakened tissues, and by their presence, action, multiplication, and effect, depress the whole animal economy, just as a local affection, such as a carbuncle, an abscess or a boil even, may prostrate and weaken one who might otherwise be considered healthy and strong. Thus, then, we see that one organ, or a part of an organ, cannot be disordered without the vital force of the whole body being depressed, and rendered liable to become a prey to disease. We must, however, remember that a certain time must elapse before such a change takes place. It is not to be understood that vital depression is immediate after, say, the bite of a poisonous reptile, or how would it be possible to save a man's life by amputating a finger which was snake-bitten, or by cauterising the bitten part and thus destroying the weakened tissues as well as the poison left in them; are we to suppose for a moment that none of the poison has entered the circulation? I should say no, and I think all, who are aware of the rapidity with which absorption takes place, and how speedily matter entering at one point is found at another, will agree with me when I say that it is only reasonable to suppose that the virus enters the blood before it is possible to take means to eradicate it from the part primarily affected; but then it mixes with blood whose vitality is unimpaired by any nervous depression, or, in other words, the vitality of the blood is stronger than that of the virus, and thus, in the treatment of snake-bites we try to sustain as well as possible the vital force by the free exhibition of stimulants. But it may be asked how does the

virus of a snake not excite the same deadly influence upon one of its own species that it does on the higher animals? I think the following is the explanation, viz.:—that which obtains in the decomposition of dead matter—in the one case the virus enters cold blood, in the other warm, and just as decomposition is retarded by cold, and accelerated by warmth, so in the cold-blooded animal the poison may multiply so slowly, or maybe its development is prevented altogether, that the system may recover from the shock sustained by the bite before the poison has had time to operate through its tardy multiplication, and therefore it never has the opportunity of acting upon a depressed state of the vital force. In the vaccine innoculation we have the very identical conditions as those in the snake-bitten warm-blooded animal, viz.:—tissue weakened by the lancet, forming a pabulum for the bioplasm of the vaccine lymph. Multiplication of the vaccine particles takes place in the weakened tissues, and at their expense, for they supply food for the nourishment of the progeny of the primary germs, which by their local action depress the vitality of the general system; and whilst their vital force is unimpaired, nay, rather heightened by the food they obtain, the vitality of the victim, as a direct consequence, is lowered and rendered susceptible to their further influence.

And to return to the Typhus disease, we will suppose a man, after a good dinner, visits a patient suffering from that fever, and it is 10 to 1 that he does not take the disease; but let that man do the same thing after a hard day's work, when he is fagged and worn out, or to repeat an expression, when his vitality is lowered, the chances will be exactly reversed. Do these facts not go far to prove that disease is just a kind of decomposition, and that its cause is a growth of bioplasm in the blood. By way of analogy let us look at a disease which is so fatal to some of the insect tribe, and a familiar disease which so often ravages our country. Of the former all of us must have observed a very familiar type, I refer to the fungus which is so fatal to flies. For the sake of conciseness, I will quote from

Professor Huxley—" In Autumn it is not uncommon to see flies, motionless upon a window pane, with a sort of magic circle in white drawn round them. On microscopic examination, the magic circle is found to consist of innumerable spores, which have been thrown off in all directions by a minute fungus called Empusa muscæ, the spore forming filaments of which stand out like a pile of velvet from the body of the fly. These spore forming filaments are connected with others, which fill the interior of the fly's body like so much fine wool, having eaten away and destroyed the creature's viscera. This is the full grown condition of the Empusa. If traced back to its earlier stages, in flies which are still active, and to all appearance healthy, it is found to exist in the form of minute corpuscles which float in the blood of the fly. These multiply and lengthen into filaments, at the expense of the fly's substance; and when they have at last killed the patient, they grow out of its body and give off spores. Healthy flies shut up with diseased ones catch this mortal disease, and perish like the others. A most competent observer, M. Cohn, who studied the development of the Empusa in the fly very carefully, was utterly unable to discover in what manner the smallest germs of the Empusa got into the fly. The spores could not be made to give rise to such germs by cultivation; nor were such germs discoverable in the air, or in the food of the fly. It looked exceedingly like a case of Abiogenesis,* or, at any rate, of Xenogenesis;† and it is only quite recently that the real course of events has been made out. It has been ascertained that one of the spores falls upon the body of a fly, it begins to germinate, and sends out a process which bores its way through the fly's skin; this having reached the interior cavities of its body, gives off the minute floating corpuscles which are the earliest stages of the Empusa. The disease is 'contagious,' because a healthy fly coming in contact with a diseased one, from which the spore bearing filaments protrude,

* Abiogenesis, or the production of living matter from not living matter.

† Xenogenesis, or the generation of something foreign.

is pretty sure to carry off a spore or two. It is 'infectious' because the spores become scattered about all sort of matter in the neighbourhood of the slain flies."*

I might refer to the fungus which has been so destructive of late to the silk-worm, and which, in a single year, entailed a loss to a district of France of no less a sum than 100,000,000 francs, and which tempted the French Government to offer the handsome reward of 500,000 francs for the use of a remedy which should prove infallible. But I will refer you to *Nature* for July 1870, for a detailed and a most interesting account of M. Pasteur's researches on the subject.

Many instances of disease being produced in the vegetable kingdom by the action of microscopic bodies could be adduced, but the mention of one will be quite sufficient for my purpose. I refer to that blight so common in our country and so familiar to us all—the potatoe disease. Any one visiting a field of diseased potatoes must have been conscious of a most loathsome smell which emanates from the diseased plants, this stench must be due to the decomposing effect of the minute fungus which covers the affected leaves, and which seems to penetrate the very heart of the tuber destroying all the starch cells of the root and leaving the potatoe a mass of disease. This fungus is easily detected by the microscope and bears a very close resemblance to mould. There can be no doubt that this is the real cause of the disease which so frequently has, more especially in Ireland, produced such misery and suffering. I do not remember a single instance, nor have I been able to find one recorded, of this disease attacking the growing plant, that is, when all its vital energies are at the maximum. On the contrary, we know that the epidemic prevails when the plant has passed maturity, and therefore has its vitality lessened; and, moreover, the blight generally comes in the wake of a blasting wind, which has further prostrated the vitality of the plant; so invariably is this the case, that the wind gets the credit of having produced

* Professor Huxley's address at Liverpool.

the epidemic, whereas, in reality, it only rendered the vegetable susceptible of its influence, which was ready to be exerted whenever the condition of the plant was suitable for the growth and development of the fungus upon it.

Many other instances might be cited to demonstrate the effect of minute organisms on living tissues, and I might enlarge very much on this part of my subject; but, as the foregoing remarks may, by some, be thought foreign to it, I will now confine myself to the consideration of the causes of decomposition in dead matter; but, before detailing my own experiments, will give the views of two or three observers who have devoted much time to the subject. I will not go beyond our own countrymen, or I am sure it will be quite impossible to keep this paper within proper bounds. I should have liked to refer to the experiments of Pasteur, Pouchet, and others, but these have been so long before the public, that I imagine most of you are fully acquainted with them.

Much difference of opinion exists on this most recondite subject. The beings themselves are so hidden from us, as it were, by their own insignificance, that were it not for the diligence of microscopists, the world at large would be quite ignorant of their very existence, not to speak of their usefulness, and mode of origin. Many, indeed, are so diminutive, that it requires the very highest powers of the microscope to detect them; and I firmly believe that myriads exist which have never been seen, but although invisible exert their appreciable force upon matter around us. It has been said that 584 different varieties of these microscopic bodies have been made out. This, I am very much inclined to doubt, as there is very good reason for supposing that the same kind of organism may present itself in different forms, as the soil upon which it grows varies in character,* or it may be, as we observe in some of the lower forms of animal life, some of these beings may require to pass through different stages of development before they arrive at maturity.

* See Photo-micrographs 1 and 2.

When we take into account, then, the exceeding minuteness of these organisms, is it to be wondered at, that it is utterly impossible to decern their germs, when we consider the enormous difference in size between the ovum and the mature animal in any instance?

In decomposing matter and in putrescible fluids we have developed a series of definite forms; and if we take, say, half-a-dozen vessels containing an infusion of different organic substances, and expose them to the atmosphere under the same conditions, we have in these several vessels forms of life appearing, presenting identical characteristics, and belonging to the same families of animalcula and confervoid growths. If these were of spontaneous origin, would the peculiarities which belong to the different varieties be present in each of the organisms by which we can name them, and classify them? Would each vessel contain certain species of microscopic life resembling each other in all respects? Is it for a moment to be supposed that these several solutions contain an arrangement of matter so identical with each other, that the innumberable atoms of which they are composed can be brought together in such a manner as to produce in the many infusions the same microsymes? is it not far more reasonable to suppose that as each vessel is surrounded by the same medium, it is through and from this that the growths proceed—that is, by the deposit of germs from the atmosphere, and their development in the fluid which provides pabulum for them? This certainly is the most rational theory, and, indeed, it is put beyond all doubt by experiment. If two flasks are filled with the same putrescible fluid, and boiled to kill all existing germs contained in them, and while the steam is issuing from the flasks they are hermetically sealed, we have the organic fluid in each flask possessing properties identical in every respect, and therefore, if the theory of spontaneous generation is correct, liable to contain the same microscopic bodies after a sufficient time has elapsed to allow of their development; but if the fluids have been pro-

perly boiled, and the flasks effectually sealed, we may wait for an indefinite period without the faintest appearance of life in them. But let one of the flasks be taken into a forest and permit the air, with what it contains suspended in it, to enter; and do the same with the other indoors, and what results do we get? Why, we have forms developed in the one which are quite absent in the other. However are we to account for this fact, by supposing, as Bastian does, that these infusorial forms of life are developed *de novo,* that they are spontaneously produced by the arrangement of molecules of dead matter? I will quote his own words on the subject—"The problem concerning the primordial formations of crystals and living things is essentially similar in kind. Any difference in degree between our present knowledge on these two subjects must not blind us as to their essential similarity. Monads and Bacteria* are produced as constantly in solutions of colloidal matter, as crystals are produced in solutions containing crystallisable matter. Crystallizable substances are definite in composition, and give rise to definite statical aggregations; whilst colloidal substances, much more complex and unstable, give rise, on the contrary, to dynamical aggregations. These dynamical aggregations, though they at first make their appearance in the form of Monads and Bacteria, are, by virtue of the properties of their constituent molecules, endowed with the potentiality of undergoing the most various changes, in accordance with the different sets of influences to which they are submitted. They are dynamical aggregates, in fact, in a condition of unstable equilibrium, and are capable of being directed into new modes of current and reciprocal molecular activity in response to changes in their medium or environment. These differences between the products met with in solutions containing crystallizable and colloidable matter respectively, may, however, be due simply to the original difference in nature between such kinds of matter. Respecting the origin of the first visible forms which

* Forms of microscopic life.

appear in either kind of solution, the evidence which we possess is precisely similar in nature. If such microscopical evidence does not enable us to get rid of the doubt that the smallest visible specks of living matter may have originated from invisible 'germs' of such organisms, neither does it any more enable us to dispense with the supposition that the smallest visible crystals may have originated from pre-existing invisible 'germs' of crystals. There is, in fact, so far as actual scientific evidence goes, *almost*, as good reason for a belief in the universal distribution of invisible 'germs' of crystals, as there is for our belief in the universal distribution of invisible 'germs' of Monads and Bacteria. The very existence of the one set of invisible 'germs' is, in fact, just as hypothetical as the existence of the other. Monads and Bacteria we do know; but concerning the existence of invisible 'germs' of Monads and Bacteria we know just as little as we do concerning the existence of invisible 'germs' of crystals."* I have not time to enter into an analysis and exposure, if it needs it, of the rashness displayed in the above statements. Bastian has set up one hypothesis, endeavouring by means of it to annihilate a much more rational one. The idea of comparing the formation of crystals with that of life seems to me to be the height of absurdity. In the one case we have the chemical substance of which the crystal is built present in the fluid; and the crystal is deposited according to laws with which we are quite familiar; moreover, we are able to determine, before the formation of crystals takes place, what manner of crystal will come into existence; or we may prevent its formation altogether by a process which would have no effect on the development of a microsyme—that is, by simply adding water or other fluid to hold the crystal in solution. Another most important distinction exists in the fact, that cold hastens crystallization, while it retards the development of microscopic life. A moderate degree of warmth encourages the growth and development of minute life, and has the

* *Nature*, June 30, 1870, page 172.

opposite effect on the formation of crystals. An excess of heat, however, prevents the production of either. It really savours little of reasoning, not to mention a knowledge of chemistry, to say that we may attribute the formation of crystals to the presence of invisible germs, just as we trace the development of animalcula to invisible germs. In the one case, we have a definite chemical compound of known composition, which we can obtain manufactured independently of any invisible germs, which we can subject, in some cases, to intense heat without involving its destruction as a chemical substance, or depriving it of its intrinsic properties. We can dissolve and re-crystallise it, and we again have it unaltered in any respect. Can such liberties be taken with an animalcule? or indeed with anything endowed with life? Most certainly not. Then, wherein does the analogy consist? They resemble each other only in one very important point, and that is, a crystal of one substance only dissolved in a fluid can be re-crystallised into that substance only, and no other; and a fluid containing the germs of Bacteria or Monads only, can give birth to these particular living bodies, and to no other. But Bastian does not stop here. He goes much farther with his hypothesis. He would have us believe that fungus spores also may arise spontaneously. Now, the spores of many fungi can be collected and examined by the microscope. I shew you some, photographed, not larger than 1-3200th part of an inch in diameter.* These can be planted, and a fungus similar to that on which they grew procured. These bodies are so minute, and of such infinitesimal weight, that there would not be the slightest difficulty in their being suspended in the atmosphere, and carried through the air. And it is beyond all doubt that they are thus transmitted, or I would not have been able to obtain this specimen, which was found on a piece of cheese, for I know it was not placed there by the hand of man. On a square inch of mouldy cheese which I examined, there must have been millions of these minute bodies, and

* See plate 1.

these were all produced in less than a week. Their power of propagation is something wonderful. Why these should be attributed to spontaneous or heterogenous generation, I am quite unable to explain. In organic fluids of different composition we have similar forms of animalcula and bioplasm produced, and these always present the same features, live the same kind of life, and resemble each other most closely in every respect. Yet we are told that their origin is not due to a parent having existed before them. If this particular kind of life is spontaneous or heterogenous, why does it always retain the same features? How is it that we have not constantly cropping up new forms? And how is it that we have not spontaneous origin of larger living beings? Is it because these are so minute, not being visible except through the microscope, and because we cannot see the primordial germ, that we are going to deny their parentage? I have not the least doubt in my own mind that these tiny beings have a pedigree as remote as any of our aristocracy, *omne vivum ex vivo.*

As the time at my disposal is limited, I must not further enlarge upon this most interesting part of my subject, but will proceed at once to refer to Professor Huxley's views on it. He evidently has most carefully weighed the evidence on either side, and although he does not insist on the impossibility of living protoplasm having originated at any time from dead matter, yet, he is, as far as I can judge, convinced that we have no proof in support of the theory of Xenogenesis; and so far as experiment has taught us, we must in the meantime attribute the origin of these minute living particles, which are the cause of putrefaction, to parents in all respects like themselves. This seems only reasonable, when we ponder the following words, which I quote from Professor Huxley:—

"Prepare a solution (much used by M. Pasteur, and often called 'Pasteur's Solution'), composed of water, with tartrate of ammonia, sugar, and yeast ash dissolved therein. Divide it into three portions in as many flasks; boil all for a quarter

of an hour; and while the steam is passing out, stop the neck of one with a large plug of cotton wool, so that this also may be thoroughly steamed. Now set the flasks aside to cool, and when there contents are cold, add to one of the open ones a drop of filtered infusion of hay, which has stood for twenty-four hours, and is consequently full of the active and excessively minute organisms known as Bacteria. In a couple of days of ordinary warm weather, the contents of this flask will be milky, from the enormous multiplication of Bacteria. The other flask, open and exposed to the air, will sooner or later become milky with Bacteria, and patches of mould may appear in it; while the fluid in the flask, the neck of which is plugged with cotton wool, will remain clear for an indefinite time. I have sought in vain for any explanation of these facts, except the obvious one, that the air contains germs, competent to give rise to Bacteria, such as those with which the first solution has been knowingly and purposely inoculated, and to the mould fungi. And I have not yet been able to meet with any advocate of Abiogenesis who seriously maintains that the atoms of sugar, tartrate of ammonia, yeast ash, and water, under no influence but that of free access of air and the ordinary temperatures, re-arrange themselves, and give rise to the protoplasm of Bacterium. But the alternative is to admit that these Bacteria arise from germs in the air; and if they are thus propagated, the burden of proof, that other like forms are generated in a different manner, must rest with the asserter of that proposition.

" To sum the effect of this long chain of evidence:—

" It is demonstrable, that a fluid eminently fit for the development of the lowest forms of life, but which contains neither germs nor any protein compound, gives rise to living things in great abundance, if it be exposed to ordinary air; while no such development takes place if the air with which it is in contact is mechanically freed from the solid particles which ordinarily float in it, and which may be made visible by appropriate means.

" It is demonstrable, that the great majority of these particles are destructible by heat, and that some of them are germs or living particles capable of giving rise to the same forms of life as those which appear when the fluid is exposed to unpurified air.

" It is demonstrable, that inoculation of the experimental fluid with a drop of liquid, known to contain living particles, gives rise to the same phenomena as exposure to unpurified air.

" And it is further certain that these living particles are so minute that the assumption of their suspension in ordinary air presents not the slightest difficulty. On the contrary, considering their lightness and the wide diffusion of the organisms which produce them, it is impossible to conceive that they should not be suspended in the atmosphere in myriads.

" Thus, the evidence, direct and indirect, in favour of Biogenesis for all known forms of life, must, I think, be admitted to be of great weight."*

The results of the experiments narrated by Dr. Huxley certainly put beyond all doubt the parentage of the enormous quantities of Bacteria developed in the inoculated flask. The same atmosphere was admitted into the several flasks containing portions of a particular fluid, and the vessels were placed in circumstances identical with each other, and yet how different are the results! In spite of this, however, we have scientific men maintaining that these Bacteria are produced spontaneously; that they are so minute as not to require a parent, because we cannot see them actually issuing from the germ. It does not seem to me to be unscientific or unwarrantable to infer from analogy how they originate. The difference in size of the germ or ovulum, which after a certain period becomes developed into the mature child, and then into the adult man, is well known to all. The ovulum measures about the $\frac{1}{120}$ of an inch in diameter, and a man some-

* Professor Huxley's address at Liverpool, 1870.

times reaches the height of 6 feet, and may weigh 18 stones. Can our minds compare two bodies of such different proportions? Conceive a man 18 stones—say a Tichborne—to be a microscopic object, and where will the ovule, which was his beginning, be? Why, by some he would be said to be of spontaneous or at least of heterogenous origin. We must not be surprised, then, if we have an animalcule, the smallest specimen of which may only measure $\frac{1}{20000}$ of an inch in diameter, that we cannot discern the germ from which it sprung. It will not be absurd to suppose that the germs of such animalcula are suspended in the atmosphere by the million. No; to me it is impossible not to feel certain that in every cubic inch of air we have suspended as many germs, which in a few warm days may be the parents of a progeny as countless as the sand. I will mention one other circumstance, known to us all, before I proceed to prove by experiment how decomposition is produced, and whence life in its most minute form emanates.

No one is ignorant of the fact, that cold retards decomposition, and that meat can be preserved for an indefinite period, if frozen and kept at a temperature below the freezing point. We also know that warm weather hastens putrefaction, so that meat which in winter will keep fresh for days, in summer will be quite unfit for food in as many hours almost. Is the rate of decomposition dependent solely upon the higher or lower temperature? Does warmth accelerate decomposition by any intrinsic property which it possesses? The following coincidence will answer the question:—Exactly commensurate with the rate of decomposition is the development of bioplasm. Before decay commences, no bioplasm can be observed on the surface of the meat; and until this bioplasm can be detected, no symptoms of decay manifest themselves. Cold retards the development of microscopic life, as we have remarked before, while it promotes crystallization; moderate warmth, on the other hand, promotes their proliferation and retards crystallization. And it is a coincidence

worthy of note, that some substances which retard decomposition, in an equal ratio retard the development of minute life, just as cold does; and thus, like cold, hinder development of the germ; and in some cases, when the agent is strong enough, not only delay its development, but actually deprive it of vitality. Thus, we have exemplified how disinfecting and deodorizing agents act. Because putrefaction is due to the development of bioplasm, and because the germs of this microscopic life are either killed or have their vitality paralyzed by the action of disinfectants, we have putrefaction delayed, or may be prevented altogether. This fact presents many features of peculiar interest to sanitarians. To demonstrate the influence of a disinfectant upon the development of life, I will relate the results of an experiment upon seeds, and I will give it *verbatim*, as I have it in my note-book:—

On *Friday, March* 17, 1871, I took 12 wide-mouth 2-oz. bottles, and into each placed a little carded cotton half-an-inch in depth. This was saturated with water, and on the top of the cotton on each bottle a few seeds of common cress were placed. On the orifice of each phial a capsule of tinfoil was fitted. and within the capsule covering seven of them, pieces of lint, saturated with solutions of carbolic acid in water, of the respective strengths, 5 grs., 10 grs., 20 grs., 30 grs., 40 grs., 50 grs., and 60 grs. to the ounce, were placed. The remaining five were covered with capsules containing lint saturated with water only.

Saturday, 18*th March.*—Applied solutions of carbolic acid to the respective capsules. The seeds shew symptoms of swelling in all the bottles.

20*th.*—Again renewed the different solutions of carbolic acid. No sign of life in any of the seeds.

21*st.*—The seeds in the five bottles that are without carbolic acid are bursting into life. None of those containing the acid vapour shew the least appearance of life, although they are swollen with the moisture. Again, the various solutions were applied to the respective capsules.

22nd.—The sprouting of the seeds in the uncharged bottles has made great progress since yesterday, while those containing carbolic vapour are as dormant as ever. No more acid was added to-day, as the lint had lost none of the carbolic odour, which is due to the impervious capsules covering the mouths of the bottles.

23rd.—Charged anew each piece of lint. Uniform and rapid growth is going on in all the uncharged bottles, whilst the seeds in the carbolised bottles are quite in the same state as before noted.

24th.—The seeds in the charged bottles are still in *statu quo,* while great progress has been made in the growth of the seeds in the other bottles.

25th.—Progress of the cress in the uncharged bottles is steady. It is now half-an-inch high. No appearance of growth in the other phials.

As I think my theory regarding the action of carbolic acid is thus far proved,* I did not add any fresh acid, but removed the capsule from the 60-gr. bottle to ascertain whether the dormant state of the seeds is due to actual death or simply to suspended animation.

27th.—The cress in the five uncharged bottles is one inch in length, and the roots are ramified through the cotton. None of the seeds in the other bottles shew signs of life; neither is there any vitality manifest in the bottle from which the capsule was removed on the 25th. Removed the capsule from the 5-gr. bottle to ascertain if life still is latent in the seeds.

28th.—The growth in the uncharged bottles is still proceeding; but as yet the seeds contained in the bottles from which the capsules have been removed shew no signs of life, and although no more acid has been added to the remaining bottles, they are all in *statu quo.*

* My opinion is that the power of Carbolic Acid as a disinfectant is due to its paralyzing effect upon the germination of microscopic germs, just as it retards, and if in sufficient quantity prevents altogether the germination of seeds.

31*st*.—Still no sign of life in these bottles, whilst the young plants fill the bottles which were uncharged. All the capsules were removed to-day to ascertain if life still exists in the seeds which have been exposed to the carbolized atmosphere.

April 1*st*.—All the seeds are unchanged, except those in the 5-gr. bottle, which to-day shew faint signs of life, very minute sprouts appearing on some of the seeds.

10*th*.—The sprouts in the 5-gr. bottle have made some, but very little progress, and do not appear as if they would ever develop into cress. None of the seeds exposed to the stronger vapour of carbolic acid have shewn the least appearance of vitality.

12*th*.—Having ascertained the property of carbolic acid, in so far as it checks, and, when strong enough, prevents altogether the maturation of the plant from the seed, I carried the experiment still farther by using in the same way solutions of carbolic acid of 1, 2, 3, 4, and 5 grs. respectively, together with an uncharged bottle.

14*th*.—I find that sprouting has taken place in all the seeds of the uncharged bottle, while in 1, 2, and 3, some of the seeds shew signs of vitality. 4 and 5, as yet, are quite dormant.

15*th*.—It is very interesting to watch the rate of growth in the seeds subjected to the different degrees of strength of the carbolic vapour. Life is apparent in all the seeds, but the rate of growth is altogether in proportion to the quantity of carbolic vapour to which the seeds are exposed. Those contained in the uncharged bottle have made considerable progress, whilst those in the 1-gr. bottle have not made so much; those in the 2-gr. not so much as in the 1-gr., and so on up to the 5-gr., where life is just beginning to manifest itself.

18*th*.—It is curious and beautiful to see the gradation in the growth of the cress. The six bottles contain quite a series of growths; for while the cress in the uncharged bottle is nearly half-an-inch in length, that in the 1-gr. is much shorter; and the rate of growth has been slower in each bottle in exact

proportion to the strength of the carbolic fumes which they individually contain, the seeds contained in the 5-gr. bottle only shewing small sprouts.

21*st.*—The rate of the growths is still in proportion to the strength of the carbolic acid solution, a regular series existing. Another feature in the experiment is this,—that some of the seeds in the 4 and 5-gr. bottles are still dormant. Does this implythat there is a delicacy in these seeds? and has the weaker solution of carbolic acid the same effect on these as a stronger solution would have upon all the seeds—strong and weak—exposed to its vapour? I have removed all the capsules to ascertain if the growth will now go on uninterruptedly, and in equal ratio, or whether the growth in any of the seeds has been permanently interfered with, and whether the seeds which at present shew no signs of life will sprout, now that the carbolic vapour is removed from them, and thus demonstrate in what way the acid really acts in a dilute solution; for it has been shewn that it really destroys the germinating power of the seeds when a strong vapour is for any length of time in contact with them.

26*th.*—The impression made upon the different lots of seed remains very much the same as when they were in contact with the carbolised atmosphere, the growth is still going on at about the same rate in the different bottles as it did during the period of their exposure to the carbolic vapour. This is most apparent in the stronger solutions, and naturally mostly so in the 5-gr. bottle, where the growth is quite stunted and the portion which before shewed no signs of life are only doing so now—and that very slowly indeed. As the strength of the acid diminishes—that is, in the 4, 3, 2, and 1-gr. bottles the growth is going on with greater rapidity in proportion to the weakness of the solution. I have given the results of this experiment in detail, as they are so full of interest and beauty, and point out in a most lucid manner the effect of this disinfectant upon life; and if we may reason by analogy, it indicates to us how it prevents decomposition in different sub-

stances, viz., by preventing the growth and development of bioplasm. I may here add, that it is to carbolic acid from the wood which is burnt in the smoking of fish, &c., that the preservative power of the smoke consists. It is volatilized by the heat, and coming in contact with the fish, destroys all germs on their surface, and also by combining with an albuminous substance of the fish, forms a coating of a compound of what I would call " carbolate of albumen," and thus shields the fish from the action of the germs suspended in the atmosphere, and by that means prevents putrefaction, and at the same time gives the fish a flavour.

An experiment in which small pieces of fresh beef were employed yielded similar results as regards the development of life. In this case the beef occupied the place of the cotton in the experiment with the seeds, and the atmosphere deposited the germs which were acted upon. On August 10th, I introduced small pieces of beef into as many wide-mouthed 2 oz. bottles, into which were fitted stoppers, hollowed on the under surface. Into the hollow portion of each stopper I adapted a piece of lint, and saturated one with water, and the rest with solutions of carbolic acid, varying in strength from 1 gr. to 30 grs. to the ounce of water. Having stoppered all the bottles, I set them aside for twenty-four hours. At the expiration of that time no change was apparent in any of the pieces of beef except that which was not exposed to the carbolic acid, and that which was in contact with the 1-gr. solution. In twenty-four hours more, however, all the pieces up to the 15-gr. solution shewed signs of decomposition; but the remainder were quite odourless till the day after, when the first trace of putrefaction shewed itself. Now, exactly at the rate in which the putrefying odour was developed did microscopic life appear on the respective pieces of beef, so that it was eminently most profuse in the bottle containing no carbolic vapour; and according to the strength of this vapour in the other bottles was bioplasm in more or less abundance. Another note-worthy fact in connection with this

experiment may be narrated—that the cells of the bioplasm were much more perfect in form, and more often nucleated, where the carbolic fumes were less strong.

Two weeks after decomposition had commenced, I again examined what *had been* the pieces of beef, for then they were all reduced to pulp, but no life could be detected, the gases emitted from the cells having destroyed their own life. This, however, I can hardly think would have taken place had the decomposing matter been in free communication with the atmosphere, as the foul gases would then have been carried off; but being pent up in the bottles, they seem to have acted as a poison to the bioplasm.

Another experiment illustrates in a most beautiful manner how a disinfectant influences the growth and development of life. A number of similar bottles as those employed in the last experiment were used, and in each a piece of fresh beef was placed. Into the stoppers of two or three of them lint saturated with water was adapted; into the remaining ones lint saturated with various solutions of carbolic acid. Then, on the top of each piece of beef a few freshly laid eggs of the blow fly were deposited, and here, just as in the case of the seeds, life first shewed itself in the bottles containing no carbolic vapour, and the time of the hatching of the remainder was prolonged in exact ratio as the strength of the carbolic acid increased. In this experiment a discovery which I thought I had made a short time ago seemed to be verified, to illustrate which I will quote almost verbatim from my note-book:—On August 15th, three days after the eggs were laid, those in the bottles containing the vapour from the 40 grs. and 50 grs. of carbolic acid solution have life developed, but there is no appearance of it in the 60 gr. bottle. I have often on previous occasions noticed a great difference in size take place in these larvæ in twenty-fours, but not so in this instance, as those first hatched are unchanged in size from yesterday morning. Is it the carbolic vapour which stunts their growth? No; because I have observed that freshly

hatched ones, when placed on meat which had undergone decomposition for some time, and which consequently was covered with bioplasm, were exposed to carbolic vapour, grew very fast—the carbolic acid, though in a solution of 12 grs. to the ounce, not affecting them in the least for some time; but in a few days they stopped growing and died, and this was due to the disappearance of bioplasm; for when I came to examine what once was a mass of perfect cell life, I found it to contain very few cells indeed, but simply what appeared to be the debris of cells. From this I concluded that these larvæ do not live on decaying matter, as is generally supposed, but subsist on the minute forms of life which bring about the change. This seems to be confirmed by the behaviour of the larvæ in this experiment; for here we have decomposition delayed by the action of the carbolic vapour, and therefore we have the development of bioplasm hindered; as a direct consequence, no food is provided for the newly hatched larvæ, which can, no more than anything else, live on air, and so no growth has been observed in them. In the evening I have it noted that life has appeared in all the bottles. This shews that even the vapour of a 60-gr. solution does not prevent germination, although it delays it. The next day I have it noted that the larvæ are not thriving, and in many cases have died, their death being due, I believe, to starvation.

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